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Spatial Data Infrastructure in India: Status, Governance Challenges, and Strategies for Effective Functioning*

Pramod K. Singh

Institute of Rural Management, Anand–388001, India {pramod@irma.ac.in}

Abstract
The paper describes the status of national spatial data infrastructure (NSDI), the spatial data infrastructure (SDI) of India in terms of its vision, data formats, metadata, various standards (metadata standard, exchange standard, and application protocol), network framework, macro- policies, data- pricing and dissemination policies, copyrights, and clearinghouse issues. It identifies the challenges of governance and proposes a framework for governance. It presents technical, financial, organisational, and a detailed account of institutional and policy-level challenges and describes the missing link between the National Map Policy (NMP) and NSDI. The paper presents strategies for effective functioning of NSDI using a strategic management model. A SWOT (strength, weakness, opportunity, and threat) analysis for the government organisations, participating in NDSI is undertaken to assess the internal and external environments of the geographic information (GI) industry in the context of NSDI. A possible strategic direction for the GI industry in India in terms of shared vision, better inter-governmental relations, co-production, and collaboration is suggested. The paper describes the strategic plans using the SWOT matrix, which are strength-opportunity strategies, weakness-opportunity strategies, strength-threat strategies, and weakness-threat strategies. Finally, the paper suggests action plans for a vibrant NSDI. Research agenda for the effective functioning of SDI in a developing country in proposed before concluding the paper. The governance framework and strategic approach presented here will be useful for the effective functioning of SDI in developing economies in general and of NSDI in India in particular.
Key words: SDI, governance, stakeholders' analysis, strategy, SWOT analysis

1. INTRODUCTION

Although the term spatial data infrastructure (SDI) is largely self-explanatory, the concept is complex and has attracted varying definitions. The Global Spatial Data

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Infrastructure (GSDI) Association has stated that spatial data infrastructures provide a basis for spatial data discovery, evaluation, and application, and include geographic data, metadata, framework, services, clearinghouse, standards, partnerships, and education and communication (GSDI 2006).

The many definitions of SDI (Rajabifard *et al*. 2003) differ in emphasis and purpose, and no clear consensus on the concept of SDI and its constituting elements and principles exists. For instance, Masser (2005), and Budhathoki and Budic 2007) emphasise the following three areas that underpin all SDIs:

- Policy and organisation (organisational, institutional, management, financial, political, and cultural issues)
- Interoperability and sharing (backbone of SDIs)
- Discovery, access, and use of spatial data (main purpose of SDIs)

Based on the above definitions, I present the various elements of SDI (Figure 1). Since SDI is an evolving concept, and people's needs and technology are changing fast, the interactions between its various components such as technology component, data component, policy and institutional component, stakeholders and socio-technical networks, are dynamic in nature. This poses the need for mediation by right kind of policy, which could facilitate better interactions between the various components of SDI. Education and awareness to the population, and better collaboration-cooperation-coordination between stakeholders are required for a vibrant SDI.

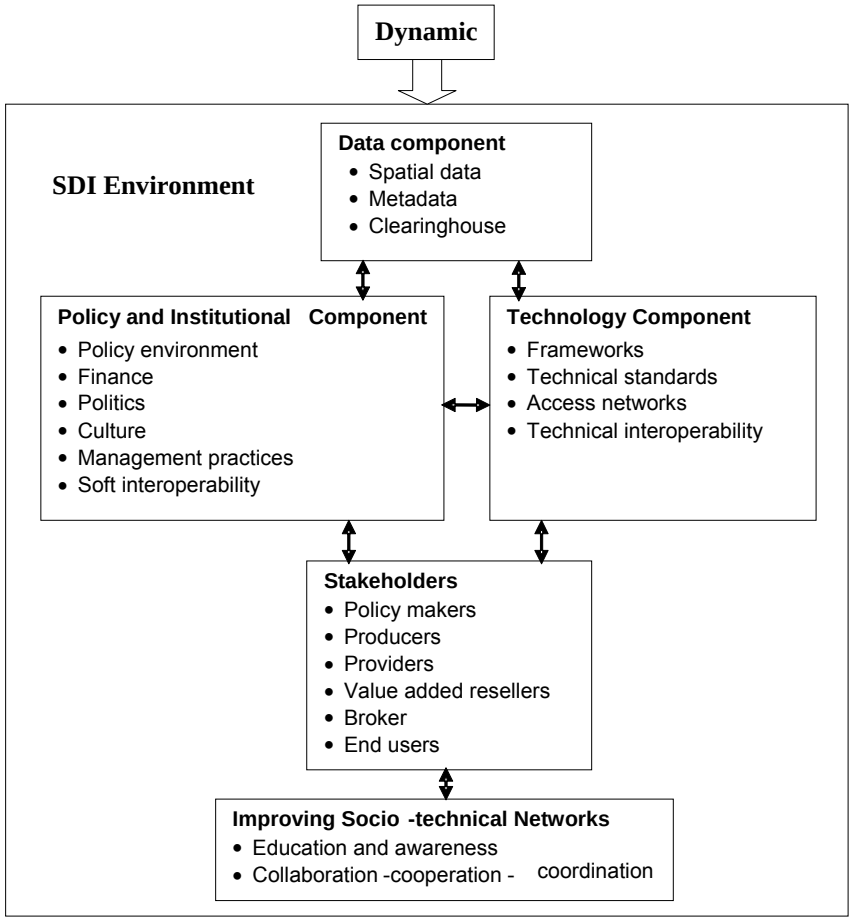
There is a need to understand the nature of socio-technical networks that constitute SDIs, including data, databases, information and communication technologies (ICTs), standards, people, institutional histories and practices, and applications (Georgiadou *et al*. 2005). Essentially, SDI subsumes technology, systems, standards, networks, people, policies, organisational aspects, geo-referenced data, and delivery mechanisms to end-users (Williamson 2004). A functional SDI could prove an important asset in societal decision and policy making (Feeney 2003), effective governance (Groot 2001), citizen participation processes (McCall 2003), and private sector opportunities (Mennecke 1997).

India has a very long tradition of systematically collecting spatial data through various organisations at national and state[1] levels, creating a broad and powerful installed base. These organisations have historically acted in a

[1] The Indian union is divided into 35 states and union territories for administrative purposes; these are further subdivided into 625 districts and 5,470 sub-districts (*talukas /blocks*).

compartmentalised manner with limited sharing of data or applications not only for citizens and the private sector, but also for other government agencies (Sahay and Walsham 1996; Singh 2005). This reflects a poor appreciation of information dissemination by these organisations. Spatial data for good governance should have no restriction on use. Considering the importance of sharing spatial data and its varied applications, the Government of India constituted a taskforce in October 2000 to suggest ways and means to create a SDI. The taskforce came out with a blueprint for national spatial data infrastructure (NSDI) – 'NSDI: Strategy and Action Plan' which defined its direction.

Figure 1: Elements of SDI



Although the NSDI portal (India GeoPortal–: www.nsdiindia.org.in) was launched by the Department of Science and Technology (DST) in December 2008, only a limited spatial metadata of the country is available. Many factors such as

technical, organisational, cultural, and institutional ones are not encouraging the geo-information (GI) industry in India.

The remaining part of the paper describes the status of NSDI in terms of its vision, data formats, metadata, various standards, and copyright and clearinghouse issues. It identifies the challenges of governance and proposes a framework for governance of SDI. Although strategies are part of the governance framework, the paper devotes a separate section on strategies for effective functioning of NSDI using a strategic management model.

2. STATUS OF SDI IN INDIA

The strategy and action plan developed by the NSDI taskforce briefly explains the vision of NSDI as "the national infrastructure for the availability of, and access to organised spatial data use of the infrastructure at community, local, state, regional and national levels for sustained economic growth" (ISRO 2001).

The NSDI taskforce has developed standards for metadata, exchange format, content standard, etc. A prototype NSDI was developed and demonstrated covering a fully-fledged metadata server and demonstration-level NSDI data and NSDI applications servers. It was expected that NSDI will ultimately emerge as a major driver for impetus to development activities and enable the emergence of an information business sector that will promote business and development activities (ISRO 2001).

It was envisaged that all major GI providers would commit to establish a GIS database in conformity with NSDI standards and serve as NSDI nodes. These nodes will be networked along with the NSDI metadata server and NSDI web-server to a NSDI clearinghouse. The NSDI clearinghouse would be the mechanism to provide access to the metadata and finally to the actual data sets from the participating agencies. NSDI gateway and user interface allows a user to query distributed collection of spatial information through metadata descriptions (ISRO 2001).

The foreword to this taskforce report by the chairman of ISRO shows a grand vision of the effort:

> Encapsulating these maps and images into an NSDI is the need of the hour and the emphasis has to be on information transparency and sharing, with the recognition that spatial information is a national resource and citizens, society, private enterprises and a government have a right to access it, appropriately. (ISRO 2001)

Rao (2007) points out that in 2001 when NSDI was envisioned, it was planned that in five years a major achievement would be made to thrust Indian spatial technology. It was envisaged that NSDI would be approved in 2002; NSDI metadata/ exchange/ agency- server/ network/ applications standards will be published by 2002; NSDI, and map policy will be redefined in 2002/03; NSDI portal will be established in 2003/04; NSDI data and application services will be operational in 2004/05; and by 2006/07 India would move to position many enterprise GIS and enable a vibrant and world class spatial-business sector of images, maps, solutions, products and services. There was no competition, no ownership-conflicts, and no departmental differences at that time. NSDI was to have brought about seamlessness in the spatial fabric of India.

However, the development did not move the way it was envisaged: it moved faster in the beginning and slower in the later phase. As stated in the introductory section, the strategy and action plan was unveiled in February 2001. The NSDI portal was ready for unveiling on July 29, 2002 in Ooty. But, at the nick of time, came a dampener – a query from the Ministry of Defence (MoD) to get clearance for the portal and its data contents (Rao 2006).

Documents on NSDI metadata standards, NSDI exchange standards, NSDI applications protocol, and NSDI network framework – all were ready by 2003, which brought out the high-level technical knowledge and professionalism of the Indian spatial technology experts (Rao 2007). The metadata standard specifies the elements needed to support the establishment of NSDI metadata, which define the information required by a prospective user. These are: to determine the availability of a set of spatial data; to determine the compliance of a set of spatial data for an intended use; and to determine the means to access a set of spatial data successfully (GOI 2003). The prototype NSDI portal was unveiled in Agra in November 2003, which later became part of the portal owned by the Department of Science and Technology (DST).

Rao (2007) mentions that there were intense discussions and debates on the map policy issue – there was overall consensus that a more pragmatic policy was required but the definition of such a policy addressing all concerns took a lot of time. The DST proposed to the MoD the commissioning of a dual series of maps: one for restricted use by the armed forces and another for unrestricted civilian use. The civilian series of maps would use a different geo-referencing system, a different projection system and a different sheet numbering system, which would be compatible with the international systems in use. MoD agreed for unrestricted use and dissemination of civilian maps series. As a precursor to NSDI, the cabinet approved the National Map Policy (NMP) in May 2005. The Government of India, constituted National Spatial Data Commission (NSDC), the apex authority for formulation and implementation of appropriate policies, strategies and programmes for the establishment, operation, and management of NSDI,

and other activities related to spatial data in the country (GOI 2006). There is also provision for constituting an NSDI executive committee, which will undertake all implementing and executive functions on behalf of NSDC, including functions delegated to it by NSDC (GOI 2006). The members of NSDC and NSDI executive committee are mostly drawn from public sector organisations, without having fair representation of other stakeholders.

Finally, the geoportal for NSDI ('India GeoPortal') was launched on December 22, 2008 by the Minister for Science and Technology and Earth Sciences with a mandate of making spatial data available to all stakeholders. The GeoPortal includes Open Geospatial Consortium (OGC) compliant web-services: WMS (web map service), WFS (web feature service), WCS (web coverage service), and WRS (web registry service) (India GeoPortal: www.nsdiindia.org.in). It will facilitate nodal agencies to uplink their metadata, product catalogues and other services through a single sign-on 128-bit encryption based secured communication.

NSDI's 'India GeoPortal' (www.nsdiindia.org.in) mentions many technical specifications for NSDI. The national spatial data exchange (NSDE) format was evolved from the digital vector data format, which was earlier designed as the national standard exchange format for the Survey of India's digital cartographic vector data. This format catered for point, line and polygon topology describing relationships among spatial features. The currently proposed format has provision to include digital images acquired by satellites and digital elevation model, and coded raster data. Furthermore, the NSDE format also accommodates various types of thematic data sets along with the associated attribute data in tabular form. According to NSDE format, data will be supplied to users as a set of files. When supplying data on media, all the files will be copied unlabelled in the same sequence with the end-of-file (EOF) mark after each file, and one extra EOF mark at the end of all files to indicate the end. In case dataset cannot be accommodated in one media, the files will be copied sequentially into additional media which will be serially numbered and indicated in the first file.

Although a large number of government and private sector organisations are involved in creating spatial data, only 17 government organisations are affiliated to NSDI by March 2009 and only a few of them have uploaded their metadata to NSDI servers. The data available with the collaborative agencies of NSDI is shown in Table 1.

Even after eight years of efforts, data pricing policy, data dissemination policy, copyright policy, and clearinghouse have not evolved. Partnership process, and education and communication components are very poor.

Table 1: Data available with the Collaborative Agencies of NSDI in India

Name of Agencies	Major Projects/Data Contents
Survey of India (SOI)	Base maps and topographical mapping on various scale
Indian Space Research Organisation (ISRO)	NRDB (natural resource data base) initiative, which is pulling data from (NRIS) natural resource information system– over 25 GIS layers relating to bio-physical and demographic features for 17 states; FASAL (Forecasting Agricultural output using Space, Agro-meteorology and Land - Based Observations); Nation-wide wasteland mapping; Nation-wide wetland mapping, Nation-wide Natural Resource Census (NRC), village resource centre (VRC) for remote areas, etc.
National Remote Sensing Centre (NRSC)	Responsible for acquisition, processing, and supply of aerial and satellite remote sensing data
Ministry of Urban Development (MoUD)	One-stop resource for urban planning and management under two ongoing mega projects– urban spatial information system, and national urban databank and indicators
Census of India (CoI)	Nation-wide demographic and socio-economic data based on surveys conducted at intervals of ten years
Forest Survey of India (FSI)	Biennial monitoring of forest resources in India
Geological Survey of India (GSI)	Geo-scientific database developed over a period of 150 years
Central Ground Water Board (CGWB)	Groundwater occurrence in different terrains
National Atlas and Thematic Mapping Organisation (NATMO)	Large number of atlases and thematic maps on environmental and associated aspects
Ministry of Agriculture	Crop acreage and production estimation (CAPE) / FASAL
India Meteorological Department (IMD)	Meteorological information
National Bureau of Soil Survey and Land Use Planning (NBSSLUP)	Nation-wide soil survey and mapping
Natural Resources Data Management System (NRDMS)	Micro-planning data on experimental basis

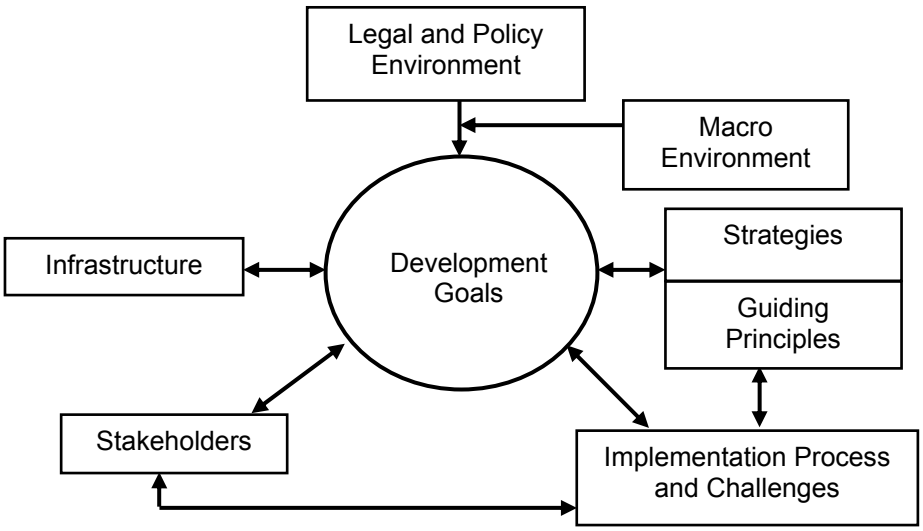
Source: Drawn from the websites of respective agencies

3. GOVERNANCE CHALLENGES

The United National Development Programme [UNDP] (1997) defines governance as the exercise of economic, political, and administrative authority to manage country's affairs at all levels. It comprises the mechanisms, processes, and institutions through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations, and mediate their differences. According to Stewart (2003), governance is a process of multi-stakeholder involvement, multiple interest resolution, compromise rather than confrontation, negotiation rather than administrative fiat (p. 76). Thus, there are several alternative conceptualisations of governance that recognise the plurality of actors. Governance in this broader sense includes the legitimate authority exercised in the application of government power and in the management of public affairs. There is greater emphasis on participation, decentralisation, accountability, and responsiveness and even broader concerns such as those of social equity and justice. Governance, therefore, has a much broader canvass than government and envisages the roles of all stakeholders: the state, private sector, civil society, and citizens at large.

The role of GIS in governance is immense and its use in the field of development has strong effect on transparency and effective implementation. Governance provides a platform for transactions between different stakeholders. This platform becomes a level playing field when different stakeholders have access to information for decision making. Based on the above discussions, I propose a working model of governance, which is shown in Figure 2.

Figure 2: Governance Framework



As it is clear from Figure 2, the entire governance process revolves around the development goals. Development goals are influenced by the macro-environment, and the legal and policy environment. Adequate infrastructure is prerequisite for the attainment of development goals. Guiding principles not only guide the achievements of development goals but also guide the implementation process. Stakeholders influence and get influenced by the implementation process and development goals. The right kinds of strategies are also needed to address the implementation challenges and realise the development goals.

The following sub-sections discuss the stakeholders' analysis, and implementation challenges of NSDI. The other elements of governance such as macro environment, as well as legal and policy environment are discussed in the institutional challenges sub-section. The infrastructure of the NSDI is already discussed in the previous section, while strategies for effective functioning of NSDI are discussed in detail in section 4.

3.1 Stakeholders Analysis

A stakeholder is any individual, group, community, association or organisation who is either affected by the project/ intervention positively or negatively or is in a position to influence the activity either positively or adversely (Lobo 2009). The Interoperability Clearinghouse (2006) defines stakeholder as –"an individual or group with an interest in the success of an SDI in delivering its intended results and maintaining the viability of its products. Stakeholders either affect the SDI or are affected by it."

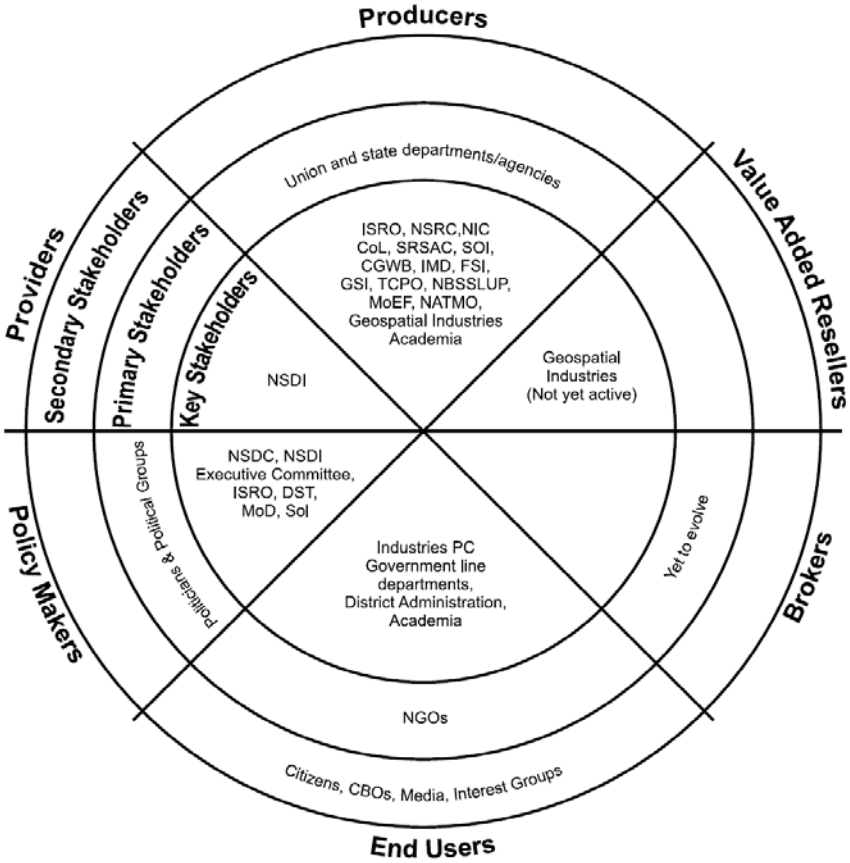
Lobo (2009) has divided stakeholders into three categories: key stakeholders – those who can significantly influence, or without whose support the project/intervention will not be successful; primary stakeholders – those who are directly affected by the intervention/project, either favourably or negatively (these are the co-called gainers or losers); and secondary stakeholders – those with an interest or role in the project/intervention but not directly affected by the intervention/project. These distinctions are not exclusive - some primary and secondary stakeholders may also be key stakeholders. The GSDI Cookbook (Nebert 2004) has classified the stakeholders into six categories:

- *Policy maker*: A stakeholder who sets the policy pursued by an SDI and all its stakeholders.
- *Producer*: A stakeholder who produces SDI data or services.
- *Provider*: A stakeholder who provides data or services to users throughout SDI.

- *Broker*: A stakeholder who brings users and providers together and assists in the negotiation of contracts between them. They are specialised publishers and can maintain metadata records on behalf of an owner of a product. Their functions include harvesting metadata from producers and providers, creating catalogue and providing services based on these catalogues.
- *Value-added reseller* (*VAR*): A stakeholder who adds some new feature to an existing product or group of products, and then makes it available as a new product.
- *End user*: A stakeholder who uses the SDI for its intended purpose.

By combining the two classification methods, stakeholders of NSDI are mapped out, which is shown in Figure 3.

Figure 3: Stakeholder Analysis of NSDI in India



Note: Please refer to the list of abbreviations for full form of the acronyms

Only producers, providers, and policy makers under key stakeholders' category are participating in the NSDI so far. Other stakeholders are often neglected in the entire process.

3.2 Implementation Challenges

Successful implementation of NSDI means that all the elements of NSDI (as shown in Figure 1) function well, a culture of sharing of spatial data develops, and no duplication of spatial data creation exists. As it is evident from discussions in section 2, all the elements of Indian SDI do not function well, culture of sharing is lacking, and duplication of data creation exists in India. The main problems relating to implementation of NSDI are: technical, institutional, organizational, and financial.

3.2.1 *Technical Challenges*

Technical challenges include frameworks, technical standards, access networks, and technical interoperability. There is a vast canvas of technical challenges relating to NSDI. According to Bishr (1998), technical interoperability has six levels: (a) network protocols, (b) hardware and operating systems, (c) spatial data files, (d) database management systems (DBMS), (e) data models, and (f) semantics.

NSDI design includes standards, metadata, nodes, search and access protocols, data clearing-house, and user interface (ISRO 2001). It represents a construction approach characterised by top-down, data centric, and centrally driven initiatives, as it has specified strategic goal and vision, prioritised plans, contributed to the definition of fundamental datasets, created a clearinghouse mechanism, and developed metadata standards (Georgiadou *et al*. 2005; Singh 2005). There could have been a bottom-up approach aiming at promoting various local initiatives and building application-specific and enterprise-wide spatial databases. There could have been an evolutionary approach to accessing, combining and using data though user-centric methodologies such as prototyping and cultivation of standards (Georgiadou *et al*. 2005). Standardisation necessarily needs to be a reflexive process, constantly needing monitoring, revisions, and new standards.

Moreover, information infrastructures are neither created from a void nor completely designed. Rather, the process of 'building' is replaced by 'cultivation' of the socio-technical installed base to gradually incorporate diverse actors in a networked environment (Budhathoki and Budic 2007). The cultivation approach has sufficient flexibility to accommodate local circumstances and practices. It also turns attention to capacity building needs at all levels, including the so-called 'inter-agency collaborative capacity' (Bardach 1998), capacity of individual

agency (Mackay *et al*. 2002), and citizen/user capacity (Tettey 2002). Technical aspects are much better done than other aspects in NSDI.

3.2.2 *Institutional/Macro-environmental Challenges*

North (1993) describes institutions as 'rules of the game' and organisations as 'players'. According to Lobo (2009), institutions are of both formal (constitutions, rules, regulations, laws, rights, etc.) and informal (sanctions, customs, mores, traditions, etc.). Robertson (1982: 93) views an institution as a stable cluster of values, norms, statuses, roles, and groups that develop around a basic social need.

In data sharing, non-technical interoperability or 'soft interoperability' as termed by Nedović-Budić and Pinto (2001) is more challenging than the technical issues. Some actors may perceive that 'information is power' and consequently will be reluctant to share data with other actors (de Man, 2006). Stakeholder involvement (participation), collaboration, and trust are important conditions. These are also major conditions for its institutionalisation (de Man 2000).

Institutional challenges are the factors external to an organisation that influence its ability to adopt or use NSDI. Institutional / macro-environmental status and challenges of NSDI can be understood by analysing policy documents: NSDI: Strategies and Action Plan, National Map Policy (NMP), and Remote Sensing Data Policy (RSDP).

The NMP announced on May 19, 2005, authorised the Survey of India (SOI) to issue guidelines for the implementation of the NMP and in particular the use of SOI products – analogue and digital (DST 2005). Consequently, guidelines were issued by SOI in 2006 (SOI 2006). The main document of NMP consists of three short pages and an annexure. The guidelines consist of four short pages, two annexes, and a digital products indent form. Besides, the guidelines also have four licenses: the media, publishing, digital, internet and value addition. Keeping in view of national security, two series of maps have been proposed: defence series maps (DSM) to cater to defence and national security requirements, and open series maps (OSM) for common civilian use.

Missing link between NMP and NSDI

The second objective of NMP is "to promote the use of geospatial knowledge and intelligence through partnerships and other mechanisms by all sections of the society" (DST 2005). This is in tune with the vision of NSDI. However, both the policy and the guidelines are silent about the partnership with major stakeholders of spatial information. NMP mandates SOI to decide issues of liberalising access of spatial data to user groups. Other spatial data creating organisations have to abide by the instructions of SOI.

Proclamation to make available all information at all SOI offices and on the website is commendable. However, even a standard 'foundation dataset' of up-to-date and geo-referenced administrative boundaries and the road networks of the entire country are not available. The absence of the foundation dataset seems to be the biggest bottleneck in large scale participation of the stakeholders of NSDI. The task is huge and SOI must have partnership with other survey agencies with legitimate rights to all.

The initial press announcement of May 19, 2005 had mentioned that aerial photographs, after masking of vulnerable areas/vulnerable points would be freely available for processing and project generation. It was also mentioned that private agencies would be permitted to carry out aerial surveys in all parts of the country using public domain datum, provided they were registered agencies and accredited by SOI. However, both the policy document and the guidelines are silent on aerial photography or aerial photographs.

Section 3 (c) of the NMP guidelines mentions that "unauthorised copying and distribution of SOI digital data are strictly prohibited" (SOI 2006). But what this copying means is not clear, because once an organisation is licensed by SOI it should be able to make copies for its organisational use. Section 4 of the guidelines states that digital data will be available in single/ multiple/ commercial licensing for general use, value adding and marketing (SOI 2006). At the same time it warns that encryption technology has been incorporated into the digital products. The original data will be destroyed if it was subject to copying activities. The issue here is how any organisation can make use of data in order to add value to it unless the decryption key is provided for various GIS analysis and value addition. The present encryption device may inhibit the growth of the geospatial industry in India. This would also defeat the very purpose of NSDI.

Section 6 (iv) mentions differential pricing of SOI products with concession to universities, research organisations and deserving NGOs (SOI 2006). This is a welcome step and I hope a generous concession will be provided to these institutions. However, data availability is the main concern.

The guidelines also mention that contour and heights will not be available in restricted zones according to MoD's instructions (SOI 2006). In the twenty first century, when high resolution satellite-derived contour information is freely available to potential enemies, contours of up to 5–10 meters may not be of strategic importance for India. Considering the importance of contours especially for water resource management and urban planning, 5–10 meter contour information should be made available for the entire country.

Today developmental activities are no more the domain of government agencies alone. Increasingly it has been felt that NGOs and other community based

organisations (CBOs) are very effective in implementation of development projects owing to their wide reach and proximity to the end beneficiaries (Singh 2005). However, there is great difficulty in accessing spatial information by NGOs and CBOs and there is no representation of members of NGOs/CBOs in NSDC. NMP and NSDI must provide a conducive atmosphere, which could promote easy access to spatial information to all stakeholders including NGOs and CBOs.

Improvement in governance cannot be limited to reforms within government but would need to encompass a wider arena including civil society. Thus, people and civil society institutions become an important link in the chain of governance. NMP and the guidelines issued in 2006 by SOI are not in tune with the new paradigm of development and governance. A handful of government departments have privileged access to spatial information while others have no access. NMP and NSDI must provide a conducive atmosphere to overrule this information asymmetry. Spatial information should go out from the exclusive club of a handful of government departments to stakeholders.

According to section 2 (b) of the RSDP, the authority to acquire and disseminate all satellite remote sensing data in India – both from Indian and foreign satellites is vested with the NRSC [National Remote Sensing Centre] (NRSC undated). In spite of having NMP and RSDP, all spatial products are not covered. Hence there is a need for an integrated spatial information policy incorporating all spatial data products and services. The new spatial information policy should not only help the growth of the spatial information industry but also promote a successful NSDI.

3.2.3 *Organisational Challenges*

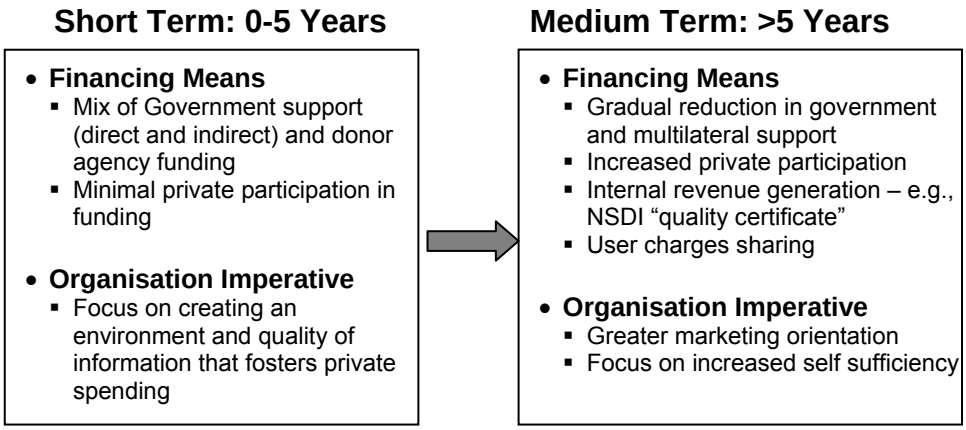
Organisations refer to a group or association, formal or informal, in which there are defined and accepted roles, positions, and responsibilities structured in some relationship to each other in order to achieve specific objectives (Uphoff 1992). Success of SDI would be a function of ability, capacity and willingness of an organisation to participate in it. The elements of inter-organisational collaboration-cooperation-coordination are often necessary for implementation and successful operation of inter-organisational system or distributed information system (Budhathoki and Budic 2007). Inter-organisational system and databases are manifestations of inter-organisational relationships (Kumar and van Dissel 1996); in the public sector they also reflect models of government and inter-governmental relations. According to Cameron (2001), inter-governmental relations vary along three dimensions: degree of institutionalisation, extent of decision making, and level of transparency. The organisational challenges relating to NSDI is elaborated in section 4.2.2.

3.2.4 *Financial Challenges*

Sustainable funding of SDI is a major issue of concern and more so in a developing country. The financial strategy for NSDI brought out by Natural Resources Data Management System (Sharma 2003) is shown in Figure 4.

According to INSPIRE (2005), data should be collected and maintained at the level where this can be done most effectively. The role of SDI is to provide an environment in which all stakeholders of spatial information can cooperate with each other in a cost-efficient and cost-effective way to better achieve organisational goals (Rajabifard *et al*. 2003). There could be many ways of funding the geo-ICT infrastructure such as revenue collection through tax, licensing and selling spatial data, selling spatial products and services, funding at the point where the data is collected, receiving donations, etc. However, public investment is needed for creation of up-to-date, accurate, and standard foundation dataset of at least administrative boundaries, and detailed road networks. Public investment is also needed for creation of up-to-date, and accurate national e-cadastre (cadastral level boundary) since government generates revenue from land registration and taxes. Once the standard foundation dataset and e-cadastre are available, the market may invest for further growth of the spatial industry.

Figure 4: The Proposed Financial Strategy for SDI in India

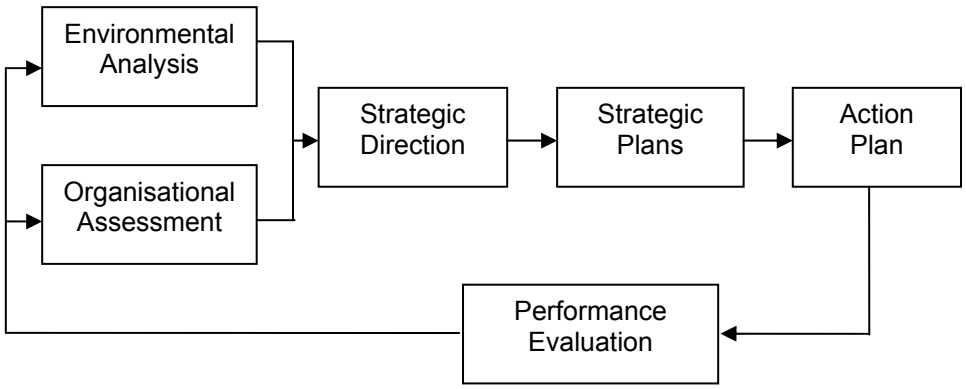


Source: Sharma (2003)

4. STRATEGIES FOR EFFECTIVE FUNCTIONING OF NSDI

The word 'strategy' comes from the Greek word 'strategia' and means planning and directing of forces toward an objective (Williams 1996). Strategic planning can be performed at national, state or at the level of a single mapping organisation. Strategic planning is a common and above all an iterative process that we all use in everyday life. The analytical process of strategic planning is the same in all cases; the only difference is in the content of the analysis and the kind of outputs produced. The strategies should be guided by the principles of transparency, accountability, efficiency, cost-effectiveness, equity, inclusiveness, responsiveness, and fairness. For the purpose of strategic analysis, I have adapted the strategic management model (Figure 5), which was initially developed by Morrison and Wilson (1996).

Figure 5: Strategic Management Model



Adapted from Morrison and Wilson (1996).

Assessment of current status and the external environment is the first step in strategic planning. SWOT (strengths, weaknesses, opportunities and threats analysis) has been used to assess the current situation and environmental factors like political, economic market or technological forces influencing the organisations involved in GI. Information for the SWOT analysis of NSDI was obtained from documents such as NSDI strategies and action plan, NMP, RSDP, and National e-Governance Plan (NeGP). Unstructured interviews with 15 persons from six participating organisations and 12 persons from other stakeholders were undertaken. Stakeholders' perspectives came out well in NSDI–8 workshop held in New Delhi during December 22–23, 2008. The SWOT analysis is undertaken in the context of government organisations using or

intending to use geospatial technology in delivering their products and services for the benefit of larger masses.

4.1 External Environment Scanning

Scanning of the external environment provides a framework for analysing the external factors affecting the organisations in terms of opportunities and threats available in the environment. The external analysis takes into account actual situations like existing threats, non-exploited opportunities, as well as possible trends and developments. Key dimensions of the external environment include the national priorities and programmes, NMP, RSDP, NeGP, technological developments, role of stakeholders', and available geo-ICT infrastructure in the country.

4.1.1 *Opportunities*

An opportunity can be defined as an external factor which can substantially contribute to the realisation of the organisation's mandate. In general, opportunities include new possibilities for cooperation, favourable government policies and regulations, a new target group, and demand for new services. Specific opportunities relating to NSDI are:

- Broad and powerful installed base for spatial data in the country
- Increasing demand for varied data products and services
- Availability of base infrastructure such as good bandwidth up to *taluka* levels
- NSDI may prove a good forum for the GI sector
- Ongoing cross-institutional initiatives on data exchange
- Scope for collaborative efforts in creation of geospatial products and services
- Value of data will increase, if the 'create once, share and use several times' approach is followed
- Convergence of technologies such as GIS, remote sensing, GPS, broadband Internet, and satellite and mobile communication will help in offering value added products and services to citizens.

4.1.2 *Threats*

A threat is an external factor that can have a substantial negative effect on an organisation's performance. Threats are challenges posed by unfavourable trends or developments in the environment that will lead to the erosion of the organisation's position if no corrective action is taken. Government organisations, involved in dealing with spatial data are facing following threats:

- Multiple agencies creating the same data i.e. improper use of financial resources by duplication of data
- Institutional inertia and lack of culture of sharing has created lock-in effects for sharing spatial information
- Both the policy and guidelines of NMP of India are silent on the partnership process with major stakeholders
- Increasing pressure for change management at organisational level for adopting the fast changing geospatial technologies
- Data security from the national security point of view, unauthorised copying/ duplication, hacking, etc.
- Pricing policy for spatial data products and services not yet clear
- Copyright issues yet to be resolved
- Data clearinghouse not yet functional
- Undefined role of each stakeholder of NSDI
- Only a small part of metadata is available from the vast storehouse of spatial data available in India
- Lack of awareness on GI by the population
- Socio-cultural factors hinders the use of spatial information
- High resolution data is populated by international players such as Google, Microsoft, etc.
- Unreliable power supply in many parts of the country is hindering access to digital information

4.2 Organisational Assessment

Organisational scanning provides a framework for analysing the strengths and weaknesses of the organisation.

4.2.1 *Strengths*

Strength is the internal characteristic that contributes substantially to good management, staff capacity, knowledge, resources, business links, etc. The strengths of government organisations working in GI sector are:

- Availability of a large base of skilled manpower which will give an edge to the organisations dealing with spatial information
- Availability of long experience with survey departments (SOI is 242 years old).

- Rich base of spatial data with reputed organisations
- Preparation in many organisations to participate in NSDI
- Standards (metadata standards, exchange format, etc.) available
- Some Indian enterprises have already proved their capabilities in IT adoption and process re-engineering

4.2.2 *Weaknesses*

Weakness is an internal characteristic that threatens the functioning of the organisation, erode the organisation's position, hamper cooperation with others, or obstruct the exploitation of opportunities. Weaknesses of government organisations involved in GI sector are:

- The geospatial programme in India is top-down, data centric, and supply oriented, and adopts the 'one size fits all' kind of approach. Hence data contents of NSDI are often insufficient to meet users' requirements
- Lot of data is available only in the analogue format
- Lack of market orientation for GI products and services
- Inefficient sectoral flow of spatial data
- Lack of understanding of users' workflow
- Incompatible process and management models hindering integration of management information system, enterprise resource planning, GIS, etc.
- Inadequate intra- and inter-organisational communication
- Lack of proper attitudinal orientation to data usage
- Culture of participatory and information efficient decision making is missing.

4.3 Strategic Direction

Strategic direction helps ensure that the organisation attains its vision and goals (Morrison and Wilson 1996). Towards this, a common vision of NSDI has been defined by NSDI taskforce which can be shared by all the organisations. In order to get various stakeholders on board, it may be essential to insist on joint development of a common and shared vision. This may entail a cultural change in the attitude towards information and the exchange of information. The process of getting stakeholders to accept and actively support the idea of an SDI will need both a strong leader and a lot of creativity in order to minimise resistance and not to de-motivate or suffocate creative initiatives (Nebert 2004).

Inter-organisational systems and databases are manifestations of inter-organisational relationships in the public sector (Kumar and van Dissel 1996).

According to Cameron (2001), inter-governmental relations vary along three dimensions: degree of institutionalisation, extent of decision making, and level of transparency. Government at all levels are the majority stakeholders of SDIs. There is no culture of sharing any information and this applies also to spatial information. Hence inter-governmental relations are of paramount importance for sharing spatial information.

Today only data producers from government organisations are in the NSDI. Public sector organisations alone cannot complete the requirement of the NSDI as the task is huge. A large number of private sector organisations are also involved in creating a huge set of spatial data. Hence improving inter-organisational collaboration, cooperation, and coordination is required not only with public sector organisations but also with private sector organisations. Co-production and collaboration model of data generation could be an important requirement. NSDI needs to develop proper pricing of spatial data such that price is not an inhibitor to its use.

As mentioned earlier, often users' workflow is not understood while providing spatial data and services. Development of any spatial data infrastructure should be centred on users' need. In the wake of poor appreciation for spatial information by citizens, emphasis on information dissemination, communication, and education is a must.

4.4 Strategic Plan

The first step towards a strategic plan is to scan the environment of the GI sector internally (from the organisations' point of view) and externally for the opportunities and threats. The SWOT matrix (shown in Table 2) could help in drawing strategic plans for organisations participating in NSDI, which in turn could help in making a vibrant NSDI.

Table 2: SWOT Matrix for NSDI in India

	Strengths	**Weaknesses**
Opportunities	**Strengths-Opportunities Strategies** 1. Publish data in NSDI at the earliest 2. Improve inter- and intra-departmental communication, involvement, facilitation and feedback 3. Exploit brand image 4. Operationalise data/ metadata servers 5. Respond to niche market 6. Address interoperability issues 7. Use reflexive standardisation process	**Weaknesses-Opportunities Strategies** 1. Develop user friendly query shell for different categories of users 2. Exploit NSDI platform for improving access and discovery 3. Improve inter-organisational collaboration-cooperation-coordination 4. Understand users work-flow and provide quality data according to users need 5. Treat citizens as partners 6. Develop enterprise-wide geo-ICT infrastructure
Threats	**Strengths-Threats Strategies** 1. Advertise success stories 2. Further liberalisation of restriction policy 3. Announce integrated spatial information policy covering all spatial data products and services 4. Establish fully functional NSDI portal for all spatial products and services 5. Adopt proper pricing of spatial data products and services 6. Adopt process-oriented management techniques 7. Make digital foundation dataset available in the public domain free of cost 8. Create innovative products and services by exploiting the convergence and fusion of various GI technologies	**Weaknesses-Threats Strategies** 1. Adopt co-production model 2. Prioritise data updating 3. Adopt emerging technology without any time lag 4. Understand users' workflow and create spatial products according to their needs 5. Publish images, maps, models, and value added products through GeoPortal 6. Use multiple sources of energy to power geo-ICT installations in remote areas 7. Adopt market orientation

The major strategic plans emerged as improvement of inter-organisational collaboration-cooperation-coordination, and market orientation. The former is already discussed in the last section while the latter is being elaborated here. Market orientation is a set of behavioural components, namely customer orientation, competitor orientation, and inter-functional coordination that keeps on creating superior value for customers and gives sustainable competitive advantage to an organization (Narver and Slater 1990). Market orientation by government organisation may facilitate the provision of services suitable for citizens' demands and more carefully guided to those that need them most (Wanna et al. 1992). Market orientation of government organisation participating in NSDI can help them in addressing societal needs better. The organisation must sell the products/services that the customer wants, not what the organisation produces (Tuladhar 2004).

4.5 Performance Evaluation

The performance-based approach uses the performance-based management (PBM) technique to evaluate, demonstrate, and improve the performance of SDI (Giff, 2006). This is based on the assumption that SDI is an infrastructure and that methods like PBM normally used for assessing the performance of infrastructure, can be used for assessing SDI. This method aims at developing performance indicators based on specific SDI objectives, which are used to measure the effectiveness, efficiency, and reliability of SDIs (Grus and Arnold 2007). For being effective SDIs must be valued and trusted—major characteristics of any institution (Broom *et al*. 1981: 17–19).

Gurstein's (2003) framework of effective use of information resources can be applicable to SDIs as well. It reveals that there are other important organisational and social structures that can enable or limit SDIs. NSDI in India is in infantile stage and is not yet fully operational. Performance evaluation can only be taken up once it becomes fully operational.

4.6 Action Plan

Action plan gives the agenda items for taking decisions. In order to have a vibrant NSDI, I propose the following actions:

- *Functional NSDI portal*: There is great need to make the national geoportal of NSDI fully functional, with proper metadata and clearinghouse facilities.
- *Announcement of integrated spatial information policy*: India needs to have an integrated spatial information policy incorporating all spatial products and services such as satellite imagery, aerial photographs, basic

and thematic maps, process and management models, and value added products, which could be generated by fusion of various geo-information and communication technologies (geo-ICTs).

- *Preparation of national GIS foundation dataset*: There are several versions of administrative boundaries and road networks available in India, which are often inaccurate. Up-to-date, standard, and accurate geo-referenced administrative boundaries, and road networks should be made available free of cost in the public domain.
- *Low cost GIS software*: In a multi-lingual country like India, low cost GIS software with vernacular language interface is of paramount importance especially when state governments would start providing GI services to citizens.
- *G-literacy*: Capacity building has to be included as an inherent part of SDI development (Enemark and Williamson 2004; Georgiadou and Groot 2002; Masser 2004; Williamson *et al*. 2003). India has very poor g-literacy. Hence for creating spatial-savvy society, efforts are needed. However, national GIS foundation dataset and low cost GIS software are a prerequisite for a better g-literacy, since these can act as catalysts.
- *National e-cadastre*: Cadastral level maps are available mainly in analogue format in India. National e-cadastre will open up new vistas for citizens, farmers, agriculture and land managers, and development workers for performing their work in better ways.
- *Enterprise-wide GI systems*: Each organisation is unique in terms of services they provide to citizens. Hence enterprise-wide GIS systems that can be scaled across a variety of platforms in a distributed computing environment are required. They should integrate spatial data and GIS, management information system, enterprise resource planning, etc. across the organisation, coupling centralised management with decentralised uses by the various tiers of the departments spread across multiple locations.
- *Regulatory/ enabling agency*: A regulatory/ enabling agency is needed for two reasons: first, to protect the interests of all stakeholders; and second, to provide a level playing field for all data producers and value adders– public sector or private sector organisations.
- *Improving inter-organisational collaboration, cooperation, and coordination:* Improvement in inter-organisational collaboration, cooperation, and coordination through dialogue process is required for a vibrant NSDI.

- *Stakeholders' involvement*: Creating forums and mechanisms for involvement of all the stakeholders of NSDI is required.

The actions discussed above are necessary for better implementation of SDI in India and many could be applicable in other developing countries.

5. RESEARCH DIRECTIONS

The ongoing SDI research is largely positivist, which is unlikely to provide rich insights on how different actors strike and sustain a dynamic balance between technology, data components, policy and institutional environment, and socio-technical networks. This calls for plurality of research perspectives and ontological diversifications–positivist, constructivist, and mixed approaches for geo-ICT research.

The current SDI knowledge base is not sufficient to inform development of sustainable SDIs (Budhathoki and Budić 2007). Ongoing SDI research is more focused on access to spatial data than on the use and utility of the infrastructure. The majority of contributions to gray and refereed literature tend to be anecdotal, unsystematic, and isolated from the broader scientific discourse. This limits the development of functional and relevant SDIs worldwide (Budhathoki and Budić 2007).

Although India has a fairly good knowledge base in technical aspects of SDI, research in the areas of architecture, standards, technical interoperability, integration strategies, spatial search engines, and data security will be required in times to come. The Indian GI sector has a very poor knowledge base in institutional and managerial aspects of SDI. Hence research is required in the areas of project management, change management for geo-ICT adoption, understanding users' workflow, and GIS alignment with other process models (management information system, enterprise resource planning, etc.). For effective use of geo-ICT and its institutionalisation at grassroots level, socio-cultural issues must be understood well through systemic research. After Indian SDI becomes operational, research will be required for its performance evaluation.

6. SUMMARY AND CONCLUSIONS

Although Indian government organisations have very long tradition of systematically collecting spatial data, there is a poor appreciation of sharing the data not only with the citizens and the private sector, but also with other government agencies. There have been efforts to create functional NSDI portal since 2000–01, only a limited spatial metadata of the country is available so far.

Out of a large set of government and private sector organisations involved in creating spatial data, only 17 government organisations are affiliated to NSDI and only a few of them have uploaded their metadata to NSDI server. The organisations participating belong only to the producers, providers, and policy makers' categories. Other stakeholders are neglected in the entire process. All the elements of Indian SDI do not function well, and duplication of data creation still exists.

The main problems relating to implementation of NSDI are technical, institutional, organisational, and financial. The NSDI should be user-centric and demand-driven rather than top-down, data centric, and supply-driven. However, institutional inertia is the major bottleneck for NSDI. Both the policy and guidelines of the national map policy are silent about partnership process with the major stakeholders. They put SOI on the driver's seat and consider the other stakeholders as merely value adders.

Some of the actions needed for establishing a vibrant NSDI in India are: the establishment of a fully functional NSDI portal for images, maps, and solutions; a national GIS foundation dataset; a mission mode approach for establishing a national e-cadastre; an integrated spatial data policy incorporating all spatial products and services; an enterprise-wide GIS for different sectors; low cost GIS software with vernacular language interface, g-literacy for creating a spatial-savvy society, improvement in inter-organisational collaboration, cooperation, and coordination, and Stakeholders' involvement. While this discussion is based on a case analysis of India, I believe it has broader implications also for other developing countries.

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List of Abbreviations

CAPE	Crop Acreage and Production Estimation
CBOs	Community Based Organisations
CGWB	Central Ground Water Board
CoI	Census of India
DSM	Defence Series Maps
DST	Department of Science and Technology
FASAL	Forecasting Agricultural output using Space, Agro-meteorology and Land - Based Observations
FSI	Forest Survey of India
Geo-ICTs	Geo-Information and Communication Technologies
GSI	Geological Survey of India
IMD	India Meteorological Department
ISRO	Indian Space Research Organisation
MoD	Ministry of Defence
MoEF	Ministry of Environment and Forests
MoUD	Ministry of Urban Development
NATMO	National Atlas and Thematic Mapping Organisation
NBSSLUP	National Bureau of Soil Survey and Land Use Planning
NeGP	National e-Governance Plan
NGOs	Non-Governmental Organisations
NIC	National Informatics Centre
NMP	National Map Policy
NRDMS	Natural Resources Data Management System
NRIS	Natural Resource Information System
NRSC	National Remote Sensing Centre
NSDC	National Spatial Data Commission
NSDI	National Spatial Data Infrastructure
OSM	Open Series Maps
PC	Planning Commission
RSDP	Remote Sensing Data Policy
SOI	Survey of India
SRSAC	State Remote Sensing Application Centres
UNDP	United Nations Development Programme